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# The differentiation history of the terrestrial planets as recorded on the moon

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Workshop on Science Associated with the Lunar Exploration  
Architecture

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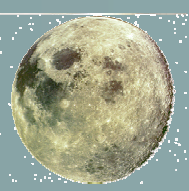
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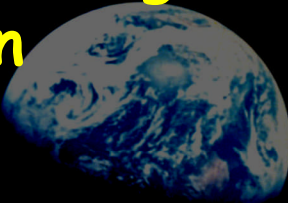
# The Differentiation History of the Terrestrial Planets as Recorded on the Moon

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# Outline

- 1) Factors Leading to Lunar Magma Ocean Model for Planetary Differentiation 
- 2) Rationale for Magma Oceans on Other Planets  
Means for early efficient differentiation  
(Works on Moon why not here?)
- 3) Some Inconsistencies between the Lunar Magma Ocean Model and Observations



# Factors Leading to Lunar Magma Ocean Model

## 1) Role of Plagioclase

Large amounts of plagioclase-rich crust  
Eu anomalies in basalt source regions



## 2) Role of KREEP

Mechanism to produce large volume evolved component

## 3) Role of Experimental Petrology

Permits predictions (E.g., ilmenite in high Ti sources  
Low pressure, volatile depleted, limited  $fO_2$ )

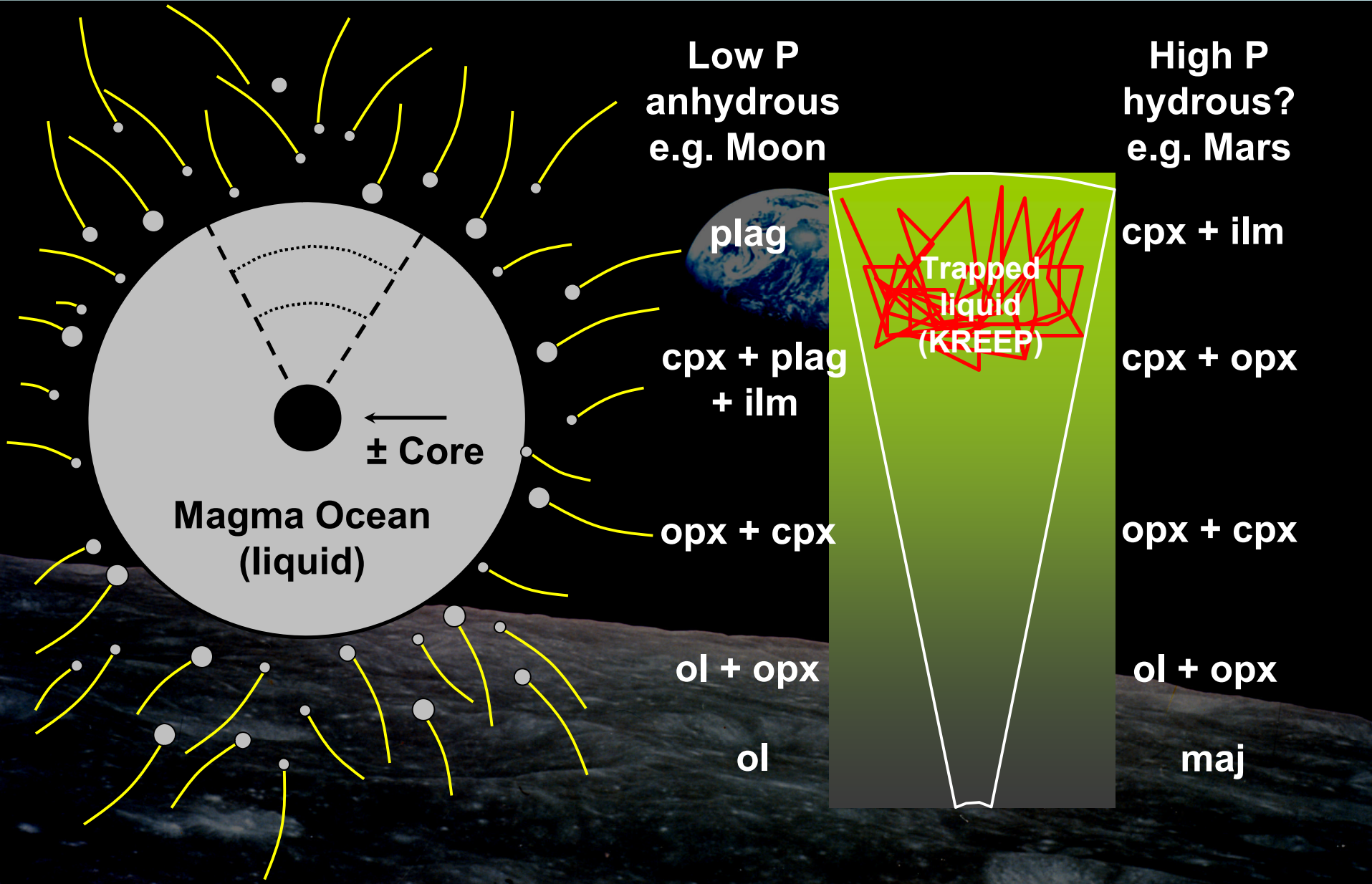
## 4) Ability to account for observed compositional variations by mixing experimentally produced sources with observed (KREEPy) materials

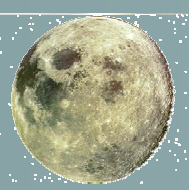




# MAGMA OCEAN MODEL

Early, Rapid, & Extensive Differentiation on a Planetary Scale





# Magma Oceans on Other Planets

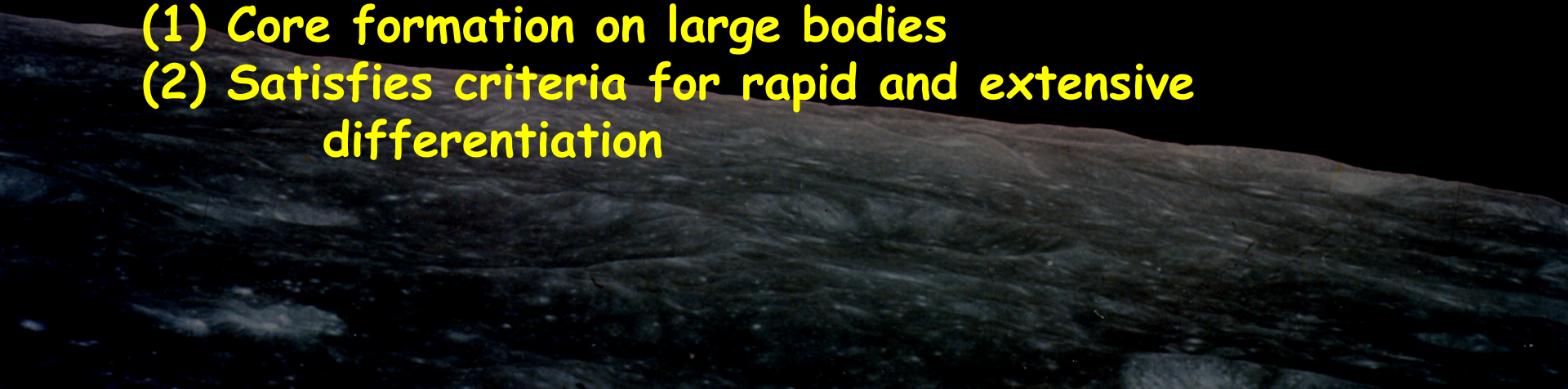
Little strong evidence that requires differentiation by  
magma ocean solidification  
No Plagioclase-rich crust, KREEP, or high Ti sources



Instead differentiation by magma ocean solidification  
simplifies differentiation models

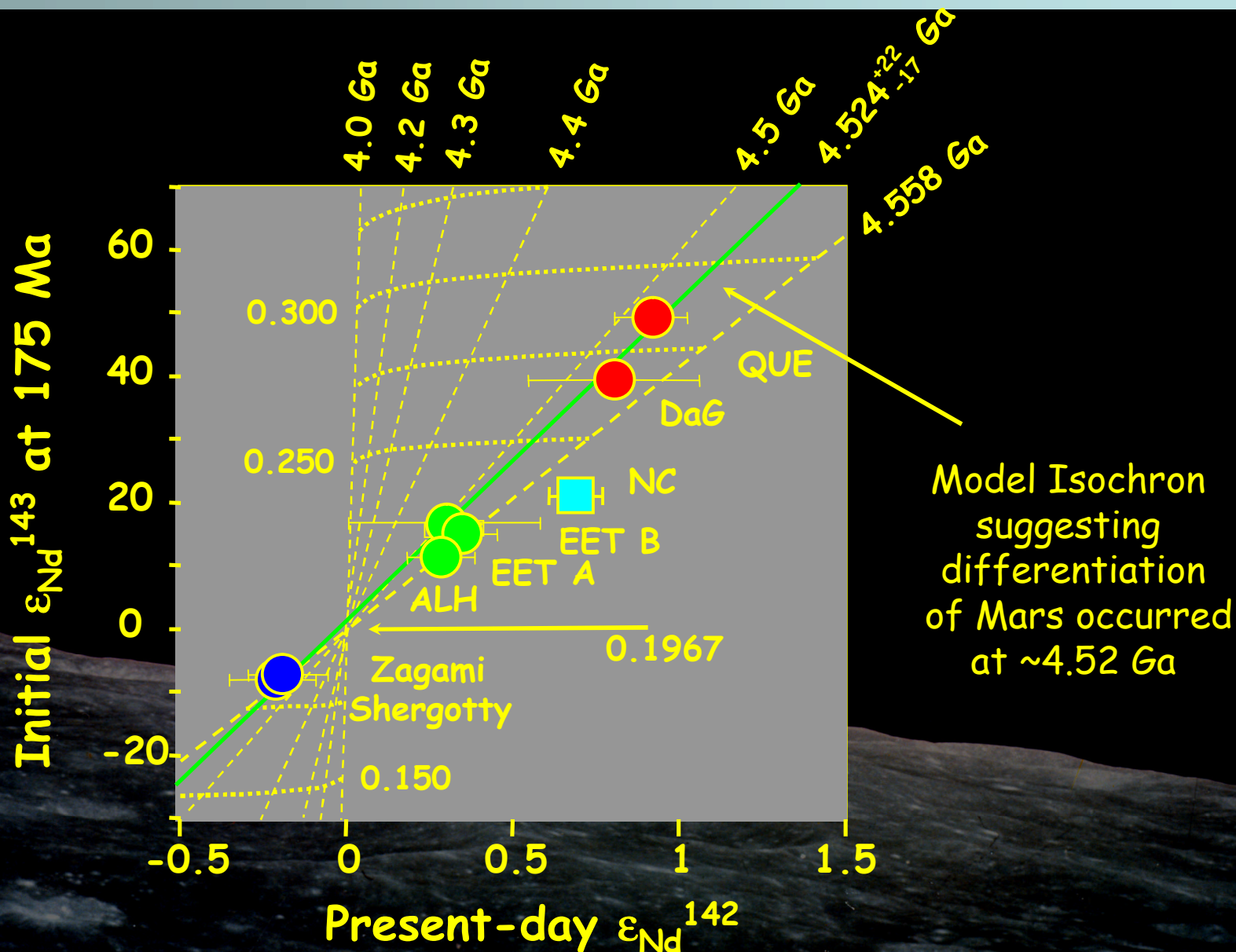
Examples:

- (1) Core formation on large bodies
- (2) Satisfies criteria for rapid and extensive differentiation





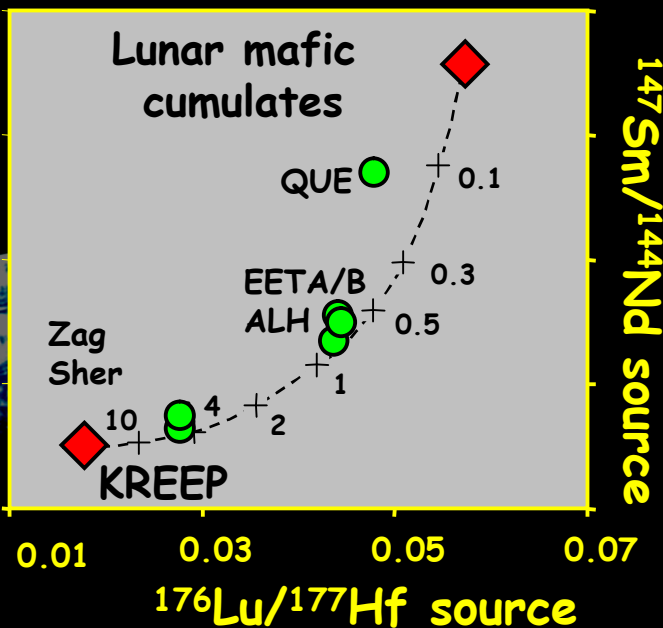
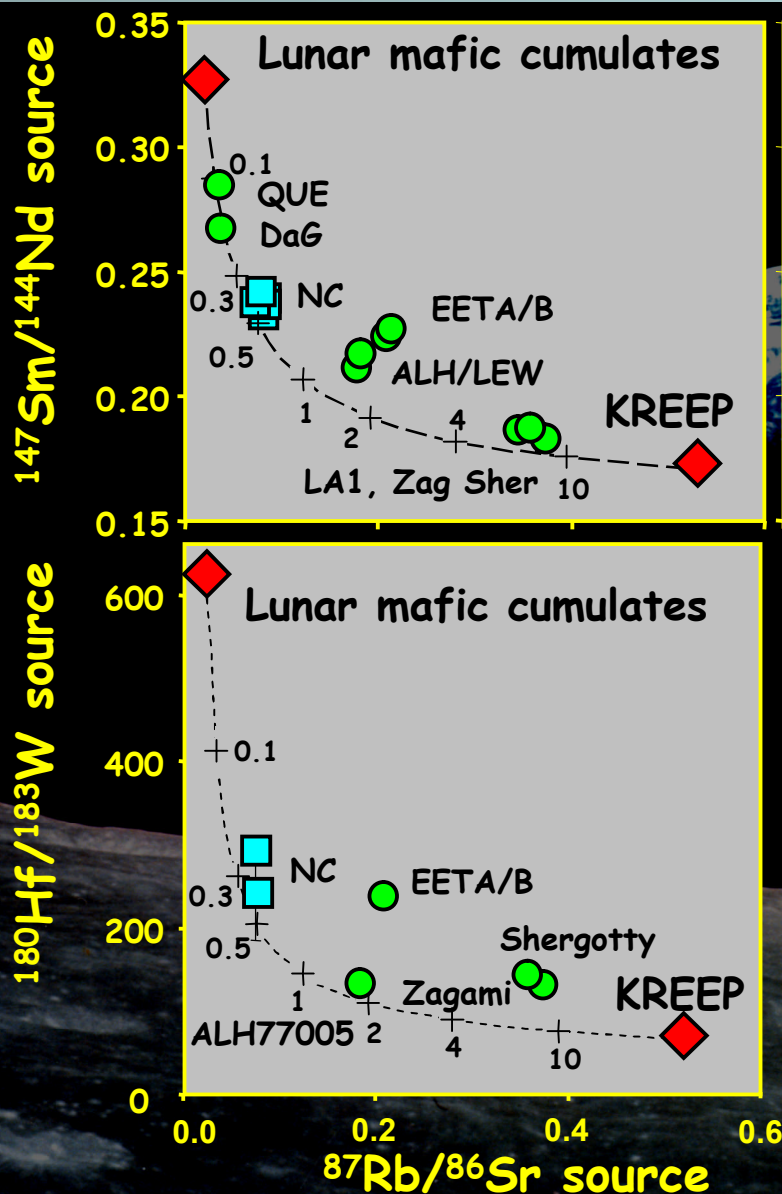
# Examples From My Research on Martian Meteorites







# Mixing of Martian Basalt Sources

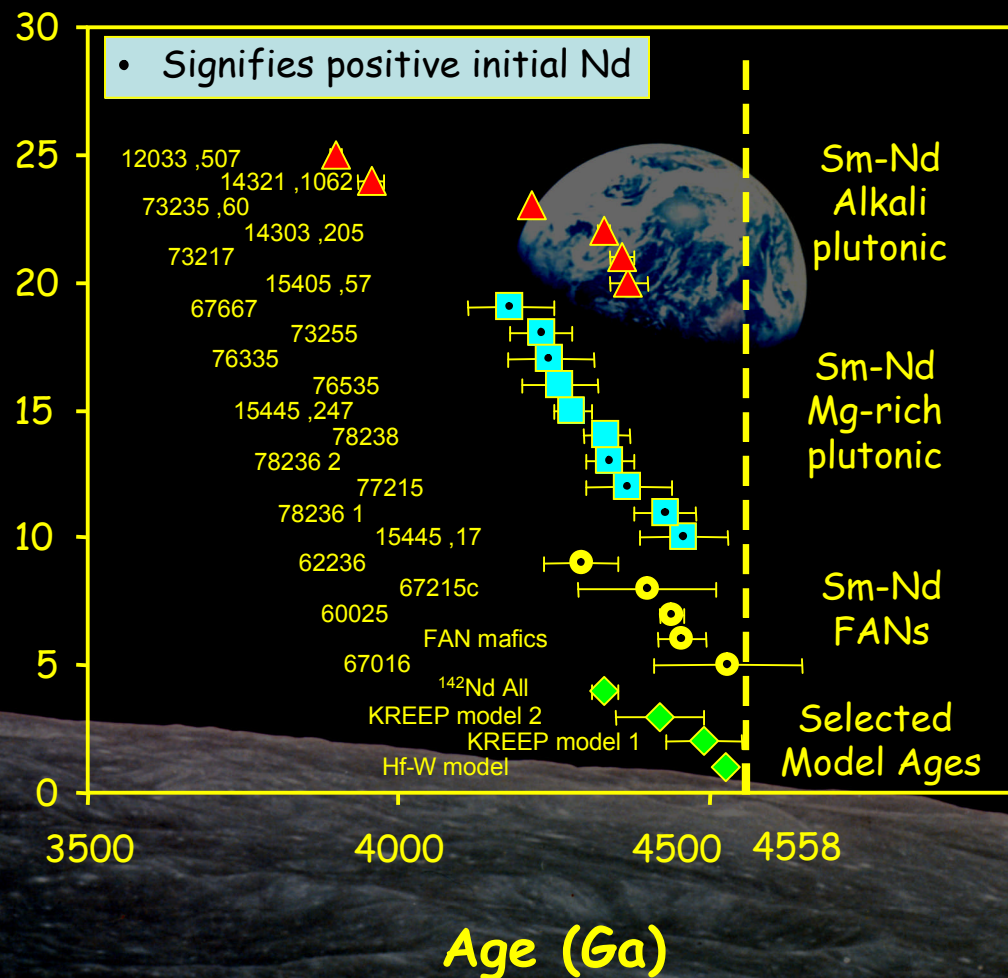


KREEP from Warren & Wasson (1979)

Mafic cumulates calculated by Snyder et al. (1992)



# Inconsistencies Between LMO Model and Ages of Lunar Differentiation and Crust Formation





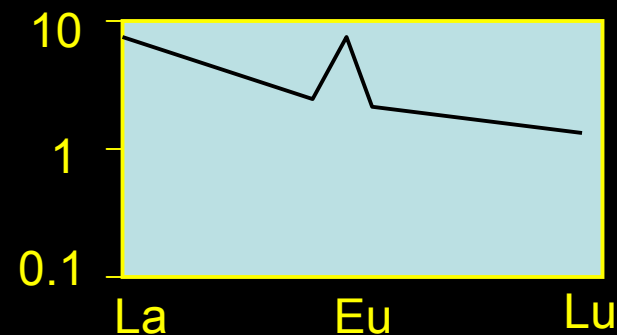
# Inconsistencies Between LMO Model and Compositions of Some Lunar Rocks

*Apollo 17 troctolite 76535*



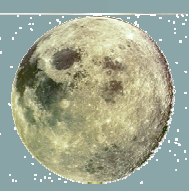
1 cm

NASA/Johnson Space Center photograph



**Olivine-plagioclase cumulate**  
**Plagioclase 58%  $An_{96}$**   
**Olivine 37%  $Fo_{88}$**





# Conclusions

- 1) Differentiation via solidification of a magma ocean is derived from geologic observations of the Moon
- 2) Although geologic observations on other bodies are often consistent with differentiation via magma ocean solidification, it is not generally required.
- 3) There are some fundamental inconsistencies between observed lunar data and the model, that will require this model to be modified
- 4) Nevertheless, the Moon is the only location we know of to study magma ocean process in detail